Returning to the Moon

Neil Farber: In order to be able to tell you about the Artemis Project, I have to give you a little bit of history about a couple of other little projects that NASA had in the past. Let me start by bringing you back to October 1957. There was a race to get satellites up into orbit. In fact, the Soviet Union won that race. They were the first to orbit a satellite around the Earth. The Soviet Union was also the first thereafter to launch an animal into orbit, the Dog Laika. The United States countered with a satellite a few months later and then was the first to not orbit, but send into space and bring back an animal safely, and that was Ham, the chimpanzee. But this was Sputnik. It was basically a 180 pound ball that had batteries on board as well as a transmitter, and it went beep, beep, beep, and that was it. [Laughter] Why spend all that money to send up this little ball as it was about the size of a beach ball with antennas?

Why spend all that money to do that? It was mainly to give the world and especially the United States the notion, "We're first, we can spy on you, we can drop a nuclear bomb on you anytime we want". In other words, to basically cow the rest of the world into submission, if you will. Well, the United States sent up Explorer 1 three months later. This was only about an 80-pound satellite. But on board, yes, it had batteries, yes, it had a transmitter, but it was transmitting data back to the United States because the United States wanted to not only beat the Soviet Union, obviously, but to explore space. This is that cute dog Laika who was in space alive only for a couple of days before she succumbed because of the fact that the air conditioning unit broke down. Thereafter, the Soviet Union was the first to put a person into space. Yuri Gagarin went up in April of 1961. He did one orbit, returned safely on the Vostok 1 spacecraft. This is Yuri Gagarin with the Vostok 1.

This is the rocket that launched him. With that, then Alan Shepherd went up for a 15-minute suborbital flight after that. President Kennedy then went to Congress and then around the country. To Congress, he said, "The US should commit itself to achieving the goal before this decade is out of landing a man on the moon and returning him safely to Earth". There were people at NASA who cheered because they had been waiting years for that pronouncement. There were people at NASA who said, "Is he out of his mind?" [Laughter] Because they had not a clue how they were going to do it.

Why the moon? Well, remember there was the space race, as I said, the US was winning. The USSR, rather, was winning. It had ordered the first satellite, orbited animals, first to orbit a man. Then, recently, there had been the Bay of Pigs fiasco. President Kennedy wanted something big to set the world on its ear and saying, "The US is in the race, too. In fact, we're going to be winning the race". Therefore, he picked the moon. He said at Rice University, "Some say, why choose the moon as our goal? Why climb the highest mountain? Why 35 years ago to fly the Atlantic? Why does Rice play Texas?" [Laughter] Some of you got that joke. That's what he said, and the whole place broke up. Because this was at Texas at Rice that he was

saying he gave this talk. He said, "We choose to go to the moon and do these other things not because they are easy, but because they are hard". Well, that pushed NASA, and NASA realized they had to get going.

They only had nine years where usually to develop, build, test, and successfully launch a rocket and a spacecraft would take anywhere 15-20 years, normally, if you were going to do it the right way. But NASA only had nine years to do it. That put pressure on the contractors to get going. There were three components to getting to the moon. The first was the Mercury program. That was a single astronaut. The maximum was 1.5 days in orbit. There were a total of six flights. Then there was the Gemini program, or as NASA says a Gemini. They were always two astronauts, and they tested aspects of the lunar emissions. How are you going to do different things? How are you going to be able to have enough energy for two weeks? Because it takes three days to get to the moon and three days back plus time to explore. How are you going to be able to do extravehicular activity? Go outside the spacecraft. Because if you go to the moon, you want to explore it.

How are you going to be able to do rendezvous and docking as part of all this? Then the Apollo missions, and there were four missions leading up to our final landing on the moon. These are the mercury flights. Some of the names may seem familiar. Alan Shepherd, the first US astronaut to go into space. John Glenn, the first to do three orbits, and then three other orbital flights after that.

Germany lasted from March of '65 until November of '66. You've got only about a year and a half for ten flights. They were pushing it. They were really pushing it. As I said, the contractors were pushing it, then four missions testing out the spacecraft. Again, you got from October of '68 to March of '69, so four flights within a six-month period of time. Then you had six moon landings with one aborted landing, and I'll talk about that in a minute, this was the Apollo Command Module and its service module. Keep this in mind because this is fairly similar in some ways to what Artemis is, and I'll talk a little bit about that. Finally, Apollo 11 launched on July 16th of '69 with Neil Armstrong, Buzz Aldrin, Mike Collins. It was the first lunar landing on July 20th of '69 in the Sea of Tranquility, this is an artist's rendition of the Eagle on the Moon. But you see that basically after Apollo 11, there were another five flights after that that actually ended on the moon.

The reason for that was that, yes, we achieved the goal. We beat the Soviet Union, we were first to the moon. But NASA actually wanted to do research on the moon, just like they want to do research in space. With this, NASA learned incredible things. But again, they were pushed because of the fact that Congress was threatening to cut their funding, NASA didn't want that because they wanted to do the research, they were pushing to get flights up as quick as they could.

Keep also this in mind. These are the six landings on the moon. You notice that they're all fairly clustered together right around this is the equator of the moon right here. A little above, a little below, but all are pretty much around the equator, which was the easiest point to reach on the moon. That was the most straightforward shot. That's one of the reasons they picked some of these particular landing sites. Well,

NASA did encounter problems because of the fact that they were rushing. Most of the problems weren't with NASA, but rather their contractors. Speaker 1: With what?

Neil Farber: Their contractors. John Glenn, he's the first American to orbit the Earth, as I said. He had problems with the automatic attitude thrusters and was using up extra thruster fuel because the thrusters weren't aligned properly. Again, this was North American who produced the capsule. Then eventually after one orbit, a warning light went on that the heat shield was not attached. Now, if your heat shield is not attached, you can say goodbye to the astronaut when he tries to reenter the Earth's atmosphere because of the intense amount of heat that's encountered. Well, it turns out that it was just a faulty signal light. But NASA figured the way, they didn't let Glenn know about any of this.

Usually what they did is after the thruster, the retro rockets were fired, they ejected them. They did a thing that allowed explosive bolts to set loose those retro rockets. Instead of that, they kept the retro rockets on because there were straps around the bottom of the spacecraft. They thought that would keep the heat shield in place until you got more bite from the atmosphere. None of that was needed because it was just, as I said, a faulty signal light. But again, this was things that weren't quite up to snuff. You see, these are the retro rockets, but you see these three straps that came across. Those were kept on until they burned off naturally. Gemini VI was supposed to be the first Gemini mission to rendezvous and dock with an Agena rocket. It was a rocket that had a docking adapter, unfortunately, because it was, again, pushed and wasn't really manufactured that well, blew up before it reached orbit.

This was Apollo. This was Gemini IX. Again, this was supposed to rendezvous and dock with one of those Agena adapters. Somebody forgot to loosen the strap before it was launched. The strap was kept on, and they were unable to rendezvous and dock with it. These are all funny but not critical. A very serious one was Apollo 1, which was going to be the first Apollo mission to test out the command module and service module in Earth orbit. Basically, they were on the pad before launch, and they did something called a plug out test, which means instead of power coming from the pad, the power comes from the service module itself, so it's an internal type of power. Unfortunately, there was a fire. All three astronauts perished. What they found was that there were problems with the wiring in the command module that set a spark. There was problems with the fact that they used pure oxygen, which heated up the fire more. There was a problem that the hatch was internal instead of external.

It opened in instead of opening out and took 90 seconds to open, which was too long. All those things were changed, but not before the three astronauts died. Then even after we landed on the moon, as I said, NASA still wanted to push it because they wanted to do more research. Everybody knows about Apollo 13, which was intended to be the third moon landing. The initial launch and transluter injection, the rocket refiring to lead it to the moon, all went well. But they suddenly lost power in the command module and began venting something into space when they were about 150,000 miles from Earth.

After they successfully got back, when they had ejected the service module upon almost reentering the Earth's atmosphere, you can see this entire side of the service module is blown off.

It turned out that there was a problem with the contractor communicating with NASA that led to it.

People wonder, why haven't we gone back? It's been over 50 years since the last time we set foot on the moon. Well, first of all, it's a high cost. The cost of the Apollo program complete was about $25.8 billion then, which is about $318 billion in today's dollars. There was a problem with political will. The space race was over once we landed, and then the Vietnam War was ongoing. There were societal issues. All this prevailed, and NASA had other interests. They had the International Space Station to attend to, and they had all unmanned missions that I don't have time to go into, which have all been incredible. NASA had its hands full, and for that reason, we hadn't gone back until recently. But recently, we developed Project Artemis, and that's what I'm going to talk about. We now have the will to go back. We now have the money to go back. The idea is, yes, we're going to go back.

Just so you know, the Saturn V, when it launched, was the most powerful rocket of its day. It was 363 feet tall, which is about the height of the Statue of Liberty, including the base.

Its first stage was the most powerful rocket ever built at 7.5 million pounds of thrust. The space launch system that now launches Artemis is not as tall as the Saturn V. But it is now the most powerful rocket ever built. The first stage with the core, as well as the two solid rocket boosters on the sides, amounts to about 8.8 million pounds of thrust. Over 1 million pounds more thrust than the Saturn V. It's needed because the Orion capsule that is used in Artemis is about 50% bigger than the Apollo command module. It seats four astronauts instead of three and is much more complex.

This is the Orion command module and its service module. By the way, I should tell you, the Space Launch System rocket is a Frankenstein rocket. By that, I mean, it's made up of different components. The core that you see here is based on the shuttle core, the shuttle rockets, and it uses an RS-25 engine, four of them, which was on the shuttle. It also uses the shuttle booster rockets. They're bigger and more powerful, but they're based on the solid rocket boosters. Meanwhile, what's called the ICPS, the intermediate cryogenic propulsion system, which is this stage here, is based on the Atlas with its second stage that was used to boost satellites into orbit. The engine is an RL-10, which is a different type of engine. Then the final component, the Orion capsule and its intermediate service module, basically is based on the Apollo era. It's a mix of different rockets.

Besides the larger size, the internal part of it is much more modern. It uses flat-screen TVs for navigation, all things that are used in the command module instead of analog switches. Instead of fuel cells, it uses solar cells. It's a mix of different things, but it's very effective.

A lot of this is new technology. It's an entirely different launch vehicle. It's based on other things, but all upgraded. It's a new command module. It's the Orion spacecraft. Four astronauts instead of three, much more updated technology, and the service module is new and built by the European Space Agency. This is all new. Artemis 1 was the unmanned test of the space launch system. It's command and service modules, and it launched on November 15th of 2022. This was a circumlunar mission. It looped around the moon, went about 6,000 miles beyond the moon, and came back. Everything of this mission was spot on perfect, except for one thing.

The Orion heat shield had breaks in it. If you had astronauts on board, it would put them at risk of being burned up.

You can see these breaks in the heat shield here, here, here, here. This is a true hole in the heat shield, not just a break.

Part of the problem was how it re-entered. They did skip technology. They thought this was a better way of dealing with it so that instead of just coming in like Apollo did or something in between, they skipped and did a wide comeback. They thought this was a better way of doing it. Unfortunately, what it meant is that you heated up the heat shield, then it cooled and got brittle, then you heated it up again. That was not a good way of doing it, actually, it turns out. They had to make the heat shield more vigorous, and they did more of a straight-in trajectory, just like Apollo did. There was another problem. These are thrusters. These are air intakes for the command module. The thrusters are based on what's called hypergolic fuel, which is very toxic. It's a fuel that, when it mixes with the oxidizer, self-ignites, but it's very, very toxic. It can cause cancer. It can cause serious respiratory illness. You don't want it anywhere near you. Yet here it is right next to the air inlet. There's going to be leftover fuel hydrazine after it lands, which would be then taken into the command module. This had to be redesigned.

All of this is a problem. First of all, the splashdown was not as accurate with Skip. You get better control, but there's less accuracy and more chance for water splashing because of the amount of time in the ocean. That needed to be adjusted. The water and hydrazine the thruster fuel can mix, and the ocean water is more likely to splash the thrusters, and that, as I said, can be taken in. Astronauts could be poisoned, and so they needed to redesign the Orion. How long does it take to redesign a command module?

This was quick, but it was three years, and that was considered quick. As I said, they relocated the air entry ports, and that took years for a new design and manufacturing. It was finally ready, and again, the heat shield was readapted. Artemis 2 finally did launch, as you know, on April 1st of 2026, and it was a flawless circumlunar flight lasting 10 days. This was the initial launch of the SLS at Kennedy Space Center. They luckily had a perfect day for it. You see, this is a complex diagram, but you see that basically they spent one and a half days around the Earth checking out the command module and the service module. Then the service module ignited and put them into this circumlunar loop. They ended up going about 6,000 miles beyond the lunar surface, and that's the farthest humans have ever

traveled into space.

These were the four astronauts on board, including Christina Koch, who is the first woman to do a circumlunar orbit or flight, and this was a picture they took from their window as they are traveling to the moon. You see the United States here,

and it was a perfect splashdown just off our coast. Unfortunately, we're not ready to actually go back and land on the moon quite yet. It's going to take several more years. NASA talks about maybe by 2029; it may be a couple of years after that. This is a much more challenging mission. Apollo was really easy. We got it done. It wasn't any big deal. This is nothing like that. We're going to be landing at the south pole of the moon, which is difficult to get to and difficult to be there. It's more challenging technology and a more challenging flight. Let me explain that to you.

These, as I pointed out before, were the six landing sites of Apollo. This is down here, where the pointer is, is where Apollo now IV will be landing on the moon. Originally, it was going to be three. That's changed.

Artemis or Artemis 3 will launch in mid-2027. It's going to be a rendezvous in Earth orbit. It's not going to go to the moon. It's now going to be the same thing as Apollo 9 was to test out all the technology before we actually go to the moon. It's going to test the rendezvous and docking because this is a much bigger lunar lander. We need to be sure we can rendezvous and dock with it accurately and also test the propulsion and life support of the lander itself.

This will be the rendezvous of Artemis 3. This is the command module and service module, and this is the Lunar Lander, which I'll show you in a minute in terms of the artist's conception, is quite a monster.

The command module and service module combined is maybe about 15 feet this way. This is what's going to land on the moon. If this is 15 feet, you can see this is probably about 100, 150 feet tall.

One of the things to know also in terms of why is this a more challenging mission, Apollo had one problem even when they were around the moon. The command module orbited the moon, while the astronauts were on the moon. Each orbit required two hours. But the command module was completely out of touch with NASA or the astronauts on the moon for half of that time because they were on the far side of the moon. That's dangerous if any kind of problem is encountered on the moon or in the command module. There is absolutely no support for anybody either way. How do you overcome this? NASA has figured it out. I'll show you in a minute. But you can see that basically if they're orbiting the moon, let's say they land here and the command module's continuing to orbit for half of it almost, they are out of touch with the astronauts on the moon, and for half of it, they are out of touch with NASA.

Artemis IV's communication will be almost continuous. It may be a few minutes where they won't have communication, but it's almost continuous. They're using

something called near rectilinear halo orbit. I don't know if you all know what a Lagrange point is. A Lagrange point is where if you have the moon, and the Earth, they each have gravity, and at some point, their gravity touches. The Earth's gravity and the moon's gravity, and it's close to the moon because the moon is so much smaller. Well, at a Lagrange point where the two gravities touch, you can orbit that point without using a lot of fuel because it just sticks there because the gravity are equal. Then what happens is you orbit with that thing that you're orbiting. It would orbit with the moon, but it would be, therefore, continuous for almost the entire time.

It uses less fuel to stay there. The problem is, we have never tried this before. We have put satellites into a Lagrange point of Earth and the sun. The James Webb Space Tellescope is at a Lagrange point between the Earth and the sun. But we have never tried to put anything at a Lagrange point at the moon, nor have we put any astronaut at a Lagrange point. They're going to need to practice this in the simulators extensively before they get it right. Come on. You see basically, this is the moon orbiting the Earth, and so the orbit last 28 days. If you're on the moon for two weeks, and it's mostly daylight, you're in continuous communication with the Earth the entire time because it's orbiting at the Lagrange point. That's what they mean by non rectilinear halo orbit.

The other problem is, as I said, the starship human landing system, HLS, is huge. It needs to include supplies, instruments, et cetera, and it will support two astronauts for a week very easily. But it needs a large amount of fuel. This thing is really big. It needs a large amount of fuel to get from the Earth to the moon. You can't launch this thing from the Earth. It's meant only to be landing on the moon and back up to the command module again.

It doesn't have enough fuel to get to the halo orbit, down to the moon, back from the halo orbit and back to Earth. That just can't happen. This is the artist's conception of the starship human landing system.

This is a diagram of it. This is the payload area. There's an elevator that takes him down to the ground. This is the methylene tank, and then the O_2 tank.

It uses liquid methane as the fuel. But I don't know if you could see it. This is an astronaut standing here. That's the astronaut. That's the Luna Rover. You see how big this thing is. Landing that's going to be a challenge. To be able to carry all the things it needs for the astronauts for a whole full week. How do you get more fuel into a rocket this big? Well, you can build a bigger rocket and launch it from Earth. But then you have to have bigger fuel tanks. If you have to have bigger fuel tanks, then you have more mass, so you need more fuel. You get into this vicious circle. That's not going to work. You could do strap on boosters in orbit, but now astronauts have to do the construction, and that's very complex and dangerous. Or you can do orbital transfer of fuel. This is what NASA endorses. This has never been tried before. We have never refueled a rocket in space.

Remember, this is microgravity. We call it weightless. It's not really weightless. It's because you're constantly falling, but your speed outweighs that. You're constantly

falling towards the Earth. It's microgravity, but it acts the same way. The fuel tends to just float. It's not going to go one way or the other. You have to have some acceleration to push it into the other place you want it to go, which is into the rocket. Again, very complex. You're also going to need not one tank. This is, let's say, the lunar lander up here. It's going to take maybe a half dozen launches of the heavy lifter space launch system that starship has to be able to refuel that tank.

It's going to require multiple launches of fuel containers, and therefore, many heavy lifter launchers are required. It's transferring cryogenic, meaning super cold fuel and oxidizer in orbit, which has never been tried before. This is all completely new.

Rendezvous and docking is inherently complex because the orbital mechanics are difficult. It's especially difficult in this case, because they're doing it in non rectilinear halo orbit, and that's never been tried before.

This would be, for example, the command module docking with the starship HLS, human landing system. This nose would dock with this nose, basically. It can be done successfully, but you better practice this a lot. That's why Artemis III is going to be in Earth orbit practicing this before we go to the moon.

There are lots of other benefits of the starship lander, good radiation protection, plenty of space for the astronaut supplies, experiments, a good environment for one week expedition. Remember that the lunar module was cramped. It was big, but it still was very cramped. They only had to stay on the moon a maximum three days. Astronauts are going to stay for at least a one week expedition. They wanted enough space the astronauts could stretch out a little bit, if you will. The landing site also has challenges. This is the South pole of the moon. Besides not a direct shot like the equator is, there's temperature extremes. The surface can reach up to 300 degrees Fahrenheit. But the craters are in constant dark, which means they're -300 degrees Fahrenheit constantly. How do you get suits that are able to tolerate that? How do you have instruments and rover, et cetera, that are able to tolerate that?

We're going to want to explore the craters because that's where ice is, and that's the whole purpose of this is to find a place we can set up a moon base so that it's the next stepping stone to go into Mars. You need to set up lighting, heaters, et cetera.

This is an image of the South pole of the moon, and you see some of it's in light, and it's pretty much in constant light because it's at the pole. But the craters and some parts of it are going to be dark, and that means -300 degrees Fahrenheit.

The Artemis IV mission, which is the actual landing, not just docking in Earth orbit, will be a 30 day mission. They're going to stay on the moon for a full week. Two astronauts will land, they'll explore the South pole for water ice, and two astronauts will stay in Orion. It's 30 days because it'll take a while to get up there, dock with the human landing system, test that out, make sure everything's working okay with that, and then land, go back, dock, et cetera. It'll be a total of a 30 day mission.

This is what it's going to look like the landing system here near one of the craters so that the astronauts can go explore it. This is another artist's conception of what it will sort of look like. Artemis V is planned to launch in 2030. I'm not sure that's going to be accurate because I don't think IV is going to get there until 2030. We're talking more like 2032, 2033. Originally, there was going to be something called Gateway, which was going to be like the international space station around the moon that everything was going to dock with. They've now canceled Gateway, so it'll just be a direct mission to the moon. Instead of the starship human landing system, they're going to be using, presumably, Blue Origin's Blue Moon lander. It's the same approach as SpaceX with the multiple launches for transfer of fuel, et cetera. But they have something called a cis lunar transporter for refueling, just a different name, but basically the same concept. This is, again, an artist's conception of the Blue Moon lander.

This is the cis lunar transporter. This is basically all fuel or oxidizer that would offload into the lander, same way that starship does. Then Artemis V mission will land up to four astronauts. They are planned to stay on the moon for up to 30 days. NASA talks about having yearly launches thereafter, but there'll be continued exploration of the South pole. The reason being there'll be a moon base. That's the whole idea that a moon base will be constructed by Apollo by the time we get to Artemis V, that the astronauts can actually sleep in, work in, et cetera, for the time they are on the moon, which would be up to 30 days.

It's an exciting time. But there are lots of things that have to be resolved. How do you achieve and stay in a non rectilinear halo orbit? We need to practice that? How do you do rendezvous and docking in a non rectilinear halo orbit? How do you safely do orbital fuel transfer? We need to practice that, and that'll be practiced in Artemis III. How do you safely explore a more hostile and extreme part of the moon? We need to develop the technology to do all this.